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by P. S. Neporozhniy

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PROSPECTS FOR THE DEVELOPMENT OF UNIFIED ELECTRIC POWER SYSTEMS IN THE USSR

/Following is a translation of an article by P. S. Neporozhniy in Gidrotekhnicheskoye Stroitel'stvo (Hydrotechnical Construction), No 5, Moscow 1960, pages 2-8./

In accordance with the planned level of power consumption (see the article by the author in Gidrotekhnicheskoye Stroitel'stvo, No 3, 1960), and on the basis of the power and energy balances worked out for individual power systems during the next 15-20 years, the breakdown of generating capacities, taking accepted output limits into account, is characterized by the data shown in table 1.

The increase in the number of utilization hours from 4,400 to 5,000 during the 1958-1980 period is explained by the increase in the relative percentage of heavy power consuming industries (electrochemical, chemical, and a number of others); the subsequent latitudinal unification of power systems, leading to a reduction in the total maximum load of unified regions; and the automation and complete mechanization of production, leveling out the regime of power consumption both as a daily and as an annual reserve. Along with the factors which have been mentioned as increasing the number of utilization hours, there are several factors contributing to a more even distribution in the load graph: the increase in relative percentage of municipal services and individual load, particularly for illumination; the increase in relative percentage of agricultural load, which does not have as intensive a graph as industry; and the reduction in the length of the workday and the work week.

The division of USSR territory by individual power systems, which will be developed primarily in the 1959-1965 period, will be as

Table 1

Index	1958	1965	1970	1975	1980
Output of electric power, billion kwh	235	540	940	1,550	2,400-2,600
Thermal power stations, billion kwh	189	440	750	1,220	1,910
Thermal output in % of total	80	82	80	79	80
Hydroelectric power stations, billion kwh	46	100	190	330	490
Hyrdroelectric output in % of total	20	18	20	21	20
Installed capacity of electric power stations, million kw	53.6	121	190	300	480
Thermal power stations, million kw	42.8	93	142	225	370
Thermal capacity in % of total	80	77	75	75	77
Hydroelectric power stations, million kw	10.3	28	48	75	110
Hydroelectric capacity in % of total	20	23	25	25	23
Utilization of installed capacity, hours	4,400	4,500	4,900	5,100	5,000

follows: a United Central Power System (OES), Central Volga Power System (ES), Southern OES, North Caucasus ES, Transcaucasus ES, Northwest OES, Kola-Kareiia ES, Ural OES, Central Siberian OES, Transbaykal and Far East OES, Yakutskaya ASSR Power Region (ER), Magadanskaya Oblast ER, Kamchatskaya Oblast ER, and Sakhalinskaya ES. Power development in the Kazakh SSR and in republics of Central Asia is also being provided.

On the basis of the ES and ER which have been mentioned, the following main unified power systems will be created during the 1959-1965 period: a United European Power System (YeYeES), which by 1965 will include the unified ES of the Center, South, Urals, and the neighboring ES of the Volga, Central and Western Ukraine, and Moldavia; and in 1970-1975, the Northwest, North Caucasus, and Transcaucasus ES, and the Central Siberian, North Kazakhstan, Central Asian, and Far East OES.

Table 2 gives some data on individual unified power systems. The over-all required power station capacity has been determined for each of the regions mentioned taking into account reserve facilities and transmissions to neighboring regions. At the same time, the necessary capacity of heat and electric power stations was determined from specifications for supplying the thermal load, while the remaining part of the over-all capacity of the ES is accounted for by condensing TES (thermal electric power stations) and GES (hydroelectric power stations). The selection between TES and GES was based on technical and economic calculations considering the actual production and transportation situation in the given region, the cost and required time for construction

Table 2

Name of OES	1965			1970		
	Total Power Consumption (billion kwh)	Maximum Load (million kw)	Consumption Met by GES Output (%)	Total Power Consumption (billion kwh)	Maximum Load (million kw)	Consumption Met by GES Output (%)
United European	300	50	12	580	100	12
Transcaucasus*	22	3.5	—	32	5.5	33
Northwest*	32	6.3	19	51	10	13
Central Siberian	76	11	—	180	30	70
North Kazakhstan	—	—	—	50	7.5	15
Central Asian	19	3.3	—	44	7	—
Transbaykal & Far East	—	—	—	20	4	—

* To be connected to the YeYeES in 1970-1975.

Table 2 (continued)

Name of OES	1975 Total Power Consumption (billion kwh)	Maximum Load (million kw)	Consumption Met by GES Output (%)
United European	900	160	13
Transcaucasus*	49	9	33
Northwest*	77	16	15
Central Siberian	300	50	70
North Kazakhstan	100	15	8.5
Central Asian	70	13	35
Transbaykal & Far East	40	7	45

* To be connected to the YeYeES in 1970-1975.

the saving in capital expenditures per unit of capacity, and the saving in operation of the station.

The YeYeES is now in existence and includes the OES of the Center, South, and the Urals. They are connected with each other by the following 400-500-kv power transmission lines: Volzhskaya GES imeni V. I. Lenin-Moscow, Volzhskaya GES-Ural, and Stalingradskaya GES-Moscow, and also by the 220-kv Stalingradskaya GES-Tsimlyanskaya GES-Nesvetaygres-Donbass line. In 1962, a ±400-kv Stalingradskaya GES-Donbass dc line will be put into operation. By 1970, the YeYeES will include the Northwest OES via the 330-kv Konakovskaya GRES (State Regional Electric Power Station)-Leningrad and Konakovskaya GRES-Belorussia power transmission lines; and by 1975, the North Caucasus OES via connection with the Southern ES over 330-kv power transmission lines. In 1975, 50 billion kwh of the total output of the YeYeES will be received from the Central Siberian OES, and 87% of the electrical energy of the YeYeES will be produced by thermal electric power stations operating on various kinds of fuel: mazut, gas, Donets coal (South), shale (Northwest), peat (North, West, and Center), and different local coals. Of the total amount of energy to be produced by thermal electric power stations, 30% will be produced by stations which burn mazut, 33% by stations burninggas, and 33% by stations burning coal (Donets and local). The cost of production per kwh at large new electric power stations being built to operate on Donets coal will be 3.3-3.8 kopecks by the end of the period under investigation. The cost will be 1.3-1.6 kopecks with mazut as fuel and 1.3-2.0 kopecks using gas. The cost per kwh at large GES will be 0.5-1.5 kopecks.

By combining the maximum loads of united power systems, the creation of the YeYeES will reduce its load by 600,000 kw in 1965 and 1.2 million kw in 1975, while the necessary emergency reserve will be reduced by 900,000 and 1.8 million kw respectively. Combining the maximum loads of unified power systems in the YeYeES and unifying the emergency reserves will provide a 2% saving in over-all maximum capacity.

By 1975, 30 billion kwh of electrical energy must be transmitted annually the Center, the Urals, and the European regions of the country from the Nizhne-Obskaya GES over two ±700-kv dc power transmission lines 1,800 km in length. The cost ofenergy at the busbars of the Nizhne-Obskaya GES will be 0.4 kopeck/kwh. Although investment in the networks for transmitting the electrical energy of the Nizhne-Obskaya GES will amount to about 2.6 billion rubles, the cost of transmission will be less than 0.5 kopeck/kwh, and the cost recovery period for the GES (including transmission lines) compared with TES of the Center operating on solid fuel will be 3-4 years.

The Transcaucasus OES will unite the Azerbaydzhan, Georgian, and Armenian power systems. The hydropower resources of these republics and the gas deposits of the Azerbaydzhan SSR form its energy base. The average weighted cost of producing energy at the busbars of the TES being put into operation with fuel calculated at cost will be 1.4 kopecks/kwh in 1975.

The Northwest OES will unite the Leningradskaya, Estonian, Latvian, Lithuanian, Belorussian, and Kaliningradskaya power systems. The energy base of the power system by 1975 will be mazut and gas, which will account for about 80% of the output of the TES. The average weighted cost of electrical energy at thermal electric power stations being put into operation with fuel calculated at cost will be about 2.8 kopecks/kwh in 1975.

The Central Siberian OES will unite the Irkutskaya, Krasnoyarskaya, Kuzbas, Novosibirskaya, Tomskaya, and Barnaul'skaya power systems. Inexpensive coals of Eastern Siberia and the unique (in terms of economic indexes and magnitude) hyrdopower resources of the Angara-Yenisey cascade form the energy base. The cost of electrical energy produced at GES will average less than 0.5 kopeck/kwh throughout the OES, and about 1.3 kopecks/kwh when taken from the busbars of the main TES. This means that it will be wise to transmit energy from Eastern Siberia to the West where the cost of electrical energy at TES operating on Kuznets coals, even in the Kuzbas Power System, is considerably higher (2.2-2.5 kopecks/kwh), and also to the Urals.

The North Kazakhstan OES will unite the Karagandinskaya, Pavlodarskaya, and Altayskaya power systems, which include Eastern, Central, and North Kazakhstan, Kustanayskaya Oblast, and rayons of the RSFSR adjacent to Kazakhstan on the North and Northeast. This powerful new power system will be created by utilizing inexpensive Ekibastuz coals and combining the operation of powerful thermal electric power stations with the hydroelectric power stations of the Irtysh cascade. The cost of energy taken from the busbars of the main thermal electric power stations operating on Ekibastuz coal will average 1.8 kopecks/kwh. The cost will be 1.1 kopecks/kwh at hydroelectric stations. By 1975, Ekibastuz coal will account for more than 65% of the total output of electrical energy.

During the 1966-1970 period, it is planned to create a 500-kv link between the North Kazakhstan /OES/ and the YeES (United Power System) of the European USSR which will provide a saving in the installed capacity of the North Kazakhstan Power System of about 500,000 kw by consolidating the load graphs and reserve capacity. During the 1970-1975 period, the North Kazakhstan ES will be connected with the YeES of Central Siberia via a 500-kv power transmission line being installed to feed the western part of Novosibirskaya Oblast, the northwestern part of Altayskiy Kray, and the southern part of Omskaya Oblast. This link will provide a saving in reserve capacity of 500,000 kw.

The Central Asian OES will unite the power systems of the Tadzhik and Uzbek SSRs, the power centers (energouzly) of Southern Kirgizia and Eastern Turkmenia, and also the Yuzhno-Kazakhstanskaya ES. The substantial stocks of gas, coal, and hyrdopower resources form the energy base of the republics of Central Asia. Energy will generally be produced at gas-burning TES, while only 6% of the energy will be produced from coal. The average weighted cost of electrical energy at the busbars of the electric power stations being put into operation with fuel calculated at cost will be 1.2 kopecks/kwh in 1975, including about 0.9 kopeck/kwh at GES and about 1.4 kopecks/kwh at TES.

The Transbaykal and Far East OES will be developed substantially by 1970 and completed by 1975. The OES will include the ES of the Buryatskiy, Chitinskiy, Amurskiy, Khabarovskiy, and Primorskiy economic administrative regions. The local coals of the Raychikhinsk, Gusinoozersk, Kharanorsk, Bikin, and Tugnuysk deposits have been adopted as the fuel base for thermal electric power stations. The average weighted cost of electrical energy at the busbars of electric power stations throughout the unified power system will be approximately 2.5 kopecks/kwh in 1975.

During the current Seven-Year Plan, a 220-kv connection will be made between the Irkutskaya system and the Transbaykal /region/. Additional connections between this OES and the power system of the Soviet Union are not planned up to 1975.

The unification of the largest power systems, firstly the YeES of Siberia and the European USSR, is based generally on the economy in utilizing the power resources of individual regions for other regions. The fuel shortage in the Ural region means that Kuznets coals must be carried a distance of 1,800 km. With powerful TES in the Urals operating on Kuznets coals mined from open pits, the cost of electrical energy with fuel calculated at cost will be about 3 kopecks/kwh. The installation of just two ±700-kv dc power transmission circuits from Central Siberia to the Urals, a distance of about 2,400 km, will make it possible to transmit 8 million kw of capacity and more than 50 billion kwh of energy annually at a cost of 1.7 kopecks/kwh while the average cost in the YeES of Siberia is 1.3 kopecks/kwh. Thus, the transmission of energy from Siberia to the Urals will save about 1.3 kopecks for every kwh received. With partial utilization of the energy of Siberian GES, the economy will be even greater.

The creation of powerful electrical connections between the YeYeES and the YeES of Siberia will provide an additional economy by reducing the installed capacity of electric power stations as a result of the consolidation of maximum load and the opportunity for lowering the total emergency reserve. At the 1975 level, this reduction in installed capacity will be 4 million kw. The unification of the YeES of Siberia with the YeYeES into a united power system of the country (YeES USSR) will at the same time make it possible to balance the [output of] GES in Siberia with GES in the European USSR. This will result in a leveling out in the annual output of GES and the output over many years close to the average for many years. The existence of powerful electrical connections will create favorable conditions for the utilization of the inexpensive energy of new GES being put into operation in Siberia during the initial period of operation.

In a unified power system, ultrahigh-voltage lines perform the following functions: transmit large quantities of energy with a large number of maximum utilization hours (4,500-6,000 hours) from big thermal and hydroelectric power stations to regions that are short of energy; transmit capacities as dictated by a change in time zones; and transmit reserve capacities as specified by repair and emergency conditions. The vast majority of lines will, first of all, transmit considerable amounts of energy over long distances in a fixed direction. Intersystem lines must have sufficient carrying capacity to be able to transmit capacity from one system to another if necessary. This is because in power systems having powerful GES, there may be a surplus or a shortage of capacity based upon seasonal factors. A reserve must be provided over intersystem connections in the event of emergency production by one of the electric power stations in the power system. Intersystem electric power transmission provides for wide centralization in the supply of electrical energy to intermediate regions. Consequently, the most complete utilization of all the benefits to be derived from unifying power systems will be possible only if there are intersystem connections with sufficient carrying capacity.

The main problem, rational solution of which provides acceptable technical and economic indexes for long-distance power transmission, is the selection of measures to provide the [necessary] transmission carrying capacity. On the basis of research and planning work, the following technical improvements were introduced in the transmission of electrical energy between the Volzhskaya GES imeni V. I. Lenin and Moscow: the reactance of the hydrogenerators and the power transformers was lowered; the fixed inertia of the hydrogenerators and the ceiling excitation of their exciters was increased: quick-operating and highly sensitive electronic regulators for the excitation of synchronous machines were developed; the wires of 400-kv lines were split; longitudinal capacitive balancing (yemkostnaya kompensatsiya) was employed;

powerful synchronous compensators were installed in 400-kv substations equipped with quick-operating excitation regulators; switching points were installed on the 400-kv line; the operating time of 400-kv protection relays and switches was reduced, etc.

These achievements made it possible to limit the 400-kv Volzhskaya GES imeni Lenin-Moscow line to two circuits.

The eastern circuit of the first 500-kv line in the world -- Stalingradskaya GES-Moscow -- was put under load and went into operation on 27 December 1959. This is a new era in the development of Soviet and world power and power equipment construction because until now, the highest voltage transmitted in the USSR and abroad (Sweden, East Germany, and France) was 400 kv.

An increase in the rate voltage of electric power transmission to 500 kv provides the following advantages: an increase in transmission carrying capacity under stable conditions of approximately 40%, or (with the same carrying capacity requirements) a reduction in volume; the possibility of complete elimination of special facilities for increasing stability (longitudinal balancing, synchronous compensators at intermediate substations, etc.); and a reduction in energy losses on the lines. As shown by a technical and economic comparison of electrical transmission at voltages of 400 and 500 kv, an increase in the rated voltage of 800-1,000 km main lines is economically wise if the capacity to be transmitted exceeds 650-700 Mw per circuit. The use of a voltage of 500 kv for intersystem connections provides more dependable parallel operation of unified power systems and improves conditions for mutual reserve.

The start of electrical transmission between the Stalingradskaya GES and Moscow will provide the opportunity for parallel operation of the power systems of the Center, Urals, Volga, and the South, and will improve conditions for the supplying of energy to power systems of the Center. With complete development of the 500-kv intermediate substations which are planned, new regions and power systems (in Lepetskaya, Voronezhskaya, Tambovskaya, Ryazanskaya, and other oblasts) will be connected to the YeES of the European USSR. After the Stalingradskaya GES-Donbass and Donbass--Tsentral'no-Chernozemnaya Oblast dc lines go into operation, it will be possible to transmit energy produced by thermal stations in the Donbass to regions of the Center over the Stalingradskaya GES-Moscow line.

The utilization of new planning developments in installing the 500-kv Stalingradskaya GES-Moscow line provided the opportunity to limit internal overvoltages (vnutrenniye perenapryazheniya) in transmission to the assigned level. This made it possible to retain the insulation standard for equipping the 500-kv line that was previously adopted for equipping the Volzhskaya GES imeni V. I. Lenin-Moscow line. Because of this, the 500-kv transformers and apparatus are being made with no increase in dimensions or cost over similar 400-kv equipment, while the basic dimensions of line structures will remain unchanged. The use of a voltage of 500 kv increases the transmission carrying capacity to 750 Mw per circuit without utilizing expensive installations for longitudinal capacitive balancing or powerful synchronous compensators in intermediate substations and with lower energy losses in transmission. In connection with the use of a new type of supporting terminal of limited strength for the termination of wires in place of a common lead-out installation on the 500-kv Stalingradskaya GES-Moscow line, the number of heavy corner anchor towers was reduced considerably: 381 corner anchor towers are being installed on the 2,061-km line while 562 were installed on the 1,835-km Volzhskaya GES imeni V. I. Lenin-Moscow line.

The use of autotransformers instead of transformers in 500-kv step-down substations, the use of 35-110-kv shunt reactors, rational grouping of open distribution installations and 500-kv substations, and the use of precast reinforced concrete elements for the installation of apparatus and buildings provided an additional saving in capital expenditures and materials. Because of the increase in voltage to 500 kv with a reduction in the insulation standard to 2.5 microfarads and the utilization of the planning developments mentioned above, capital expenditures were reduced 5% and operating expenditures 13% over the 400-kv line.

In 1959, work started on the first industrial dc transmission [line] in World practice with a carrying capacity of 750 Mw. It will connect the Stalingradskaya GES with the ES of the Donbass and will serve as one of the links of the YeYeES. The energy will be transmitted over a two-wire aerial line a distance of 473 km with a voltage of 800 kv between wires and ±400 kv with respect to ground. The cost of transmitting energy will be about one kopeck/kwh.

The creation of power systems in the European USSR and Central Siberia will provide for the installation of 330- and 500-kv power transmission lines. Lines of 500 kv will be used widely in USSR power practice for transmitting the capacity of outlying electric power stations and for intersystem connections betwen Central Siberia, Kazakhstan, the Urals, and the Center up to 1975. During the Seven-Year Plan, 1959-1965, 11,000 km of 500-kv lines and 7,000 km of 330-kv lines will be put into operation. In 1966-1975, it is planned to construct about 18,000 km of 500-kv lines and 11,000 km of 330-kv lines.

The unfication of the united power systems of the European USSR and Central Siberia, which will provide over 85% of the total electrical energy consumed in the USSR in 1975, can only be accomplished by installing electric power transmission lines with a large carrying capacity to transmit about 50 billion kwh of energy produced by the very large GES on the Yenisey and Angara and the TES being installed on the basis of the inexpensive brown coal mined from open pits in the Kansko-Achinsk basin to the Urals. The need for transmission has arisen because an annual power shortage will occur in Ural regions and in central oblasts of the USSR by 1970-1975.

The development of techniques for transmitting energy over long distances with high-votage alternating and direct current prepared the way for the creation of the YeES USSR. To provide a carrying capacity of 2-2.5 million kw per circuit on 2,000-2,500 km intersystem connections at a sufficiently low transmission cost requires the introduction of a new and higher rated voltage. An ac voltage of 700 kv and a dc voltage of ±700 kv are being investigated as such voltage standards. The selection of current and rated voltage will depend upon definite technical and economic indexes, the determination of which requires scientific and experimental research into a number of problems. These problems include, firstly, a determination of the proper insulation standard for lines and substation equipment in the transmission of alternating and direct current in light of available facilities for limiting overvoltages, the behavior of insulation at operating voltage, and the effect of ordinary contamination on the durability of the outside insulation.

The selection of a transmission network must be made by considering the development of power systems and the supplying of energy to regions through which the transmission lines which are planned will pass.

The manufacture of 700-kv ac equipment will not present any particular difficulties since at the present time, both in the Soviet Union and abroad, designs of 600-650-kv equipment have been produced with insulation standards that are close to what is required for 700-kv equipment. Therefore, the possibility of using an ac voltage of 700 kv in the next 5-10 years will be determined chiefly by economic considerations.

Table 3 shows the results of preliminary planning work and technical and economic research which indicate that for main-line transmission of 2,400 Mw over a distance of 2,000-2,500 km, it is best to use ±715-kv direct current with a conductor cross section of 4 x ASO — 700 per line (calculations were based on a Yenisey-Ural route). The transmission of 4,800 Mw requires two-circuit lines with a voltage of ±715 kv.

To improve technical and economic indexes for the transmission of alternating and direct current, it is necessary to continue development of new and more modern designs of towers and equipment, further simplify transmission networks and substations, and reduce capacity and energy losses in transmission.

Table 3

Indexes for Main-Line Transmission (2,400-Mw Carrying Capacity) Over a Distance of 2,000-2,500 km	±715-kv DC Amount	%	700-kv AC Amount	%
Capital expenditures, rubles/kw	534	100	876	164
Lines	421	100	675	160
Substations & other installations	113	100	200	177
Transmission losses, million kwh	1,212	100	1,852	153
Lines	826	100	1,410	171
Substations & other installations	386	100	442	114
Cost of transmission, kopecks/kwh				
a) With the cost of losses at 0.35 kopeck/kwh	0.41	100	0.67	163
b) With the cost of losses at 6 kopecks/kwh	0.92	100	1.51	164

To improve the supply of electrical energy in European countries of the people's democracies, the 11th Session of the Council for Economic Mutual Assistance, held in May 1959, adopted a recommendation to unify the power systems of these countries, including western regions of the USSR. In addition to the direct transmission of electrical energy, intersystem functions will also be carried out: mutual aid under emergency conditions, exchange of capacity as stipulated by joint coverage of the load graph, etc.

One of the main tasks in completing the electrification of the USSR is increasing the amount of territory covered by electric power networks. The most effective and economical methods for complete electrification are the centralized production of electrical energy on the basis of large thermal and efficient hydroelectric power stations, and the development and unification of power systems with new regions which are now receiving electrical energy in extremely limited quantities from uneconomical low-capacity installations being connected to them (at the start of 1959, there were more than 100,000 small stationary electric power stations in the USSR, including about 50,000 agricultural stations).

Further development of power systems and complete electrification of the USSR, including regions which are being newly developed, will require during the 1959-1975 period the construction of about 900,000 km of power transmission lines of 35 kv or higher (about 4 km per 1,000 kw of newly installed capacity) and 4.2 million km of 10-0.4-kw distribution lines, including 2.9 million km (about 130 km per 1,000 kw of agricultrual load) for agriculture and 1.3 million km (about 40 km per 1,000 kw of municipal services and individual load) in cities. The total length of electric power transmission lines with a voltage of 35 kv or higher now in existence or planned for installation is as follows: 88,400 km in 1958, 299,000 km in 1965, 516,000 km in 1970, 1 million km in 1975, and 1.5 million km in 1980. The average annual rate of introduction of 35-100-kv lines during the 1970-1975 period will be about 100,000 km. A rough approximation of what is required to complete the program of network construction in the 1959-1975 period is as follows: for the electrical networks of power systems of 35 kv or higher, step-down substation transformers with a total capacity of 1.07 billion kva; for 10-0.4-kv city distribution networks, 130 million kva will be required; and for 10-0.4-kv rural distribution networks, 100 million kva will be required (the total capacity of all step-down transformers including 6-10- and 25-kv transformers for industrial enterprises and electric traction will total about 3.5 billion kva).

Planned investment in the construction of electrical networks during the 1959-1980 period, including distribution networks of 10 kv or less, will account for 40% of the total capital investment in USSR power development. Capital investment in the construction of electrical networks of power systems as a percentage of total investment in the development of power systems will increase as follows: 12.6% for the 1952-1958 period, 26.5% for the 1959-1965 period, 43.7% for the 1966-1975 period, and 46% for the 1976-1980 period.

Table 4 gives some data on the construction of electrical networks during 1959-1980.

5711

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Type of Installation	1959-1965	1966-1970	1971-1975	1976-1980	Total for 1959-1980
Kilometers of Intersystem Transmission Lines to be Introduced					
Direct current transmission	500	—	8,000	3,000	11,500
500-kv transmission lines	10,700	8,000	10,000	15,800	44,500
330-kv transmission lines	7,200	5,000	6,000	10,000	28,200
220-kv transmission lines	32,100	20,000	25,000	33,000	110,100
110-154-kv transmission lines	81,000	100,000	125,000	190,000	496,000
35-kv transmission lines	80,000	150,000	200,000	250,000	680,000
Total	211,000	283,000	374,000	501,800	1,371,800
Step-Down Substations & Transformer Points to be Introduced (1,000 kva)					
Step-down substations, 35 kv or higher	210,000	360,000	500,000	700,000	1,770,000
10-0.4-kv city & agricultural transformer points	60,000	70,000	100,000	150,000	380,000
6-10 and 25-kv transformers for industry and electric traction	80,000	90,000	130,000	200,000	500,000
Total	350,000	520,000	730,000	1,050,000	2,650,000